EXHIBIT B

AVC-158

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION
ORGANISATION INTERNATIONALE DE NORMALISATION
ISO/IEC JTC1/SC2/WG11
CODING OF MOVING PICTURES AND ASSOCIATED AUDIO

ISO/IEC JTC1/SC2/WG11
MPEG91/ 221
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Source: NHK(Japan Broadcasting Corporation)
Title: Proposal for MPEG2 Video Coding Algorithm (#26)
Purpose: Proposal

1. INTRODUCTION

This document provides a description of the video coding algorithm we propose for the Kurihama tests. The proposal is submitted by a group composed of NHK, NEC, Sharp, Toppan, GCT, and Waseda Univ. in the framework of a subgroup of Japanese collaboration. The preregistration number is 26.

This scheme is based on hybrid DCT coding with motion compensated prediction. The coding is carried out on a field basis with interlaced scanning. Both interfield and interframe motion compensated prediction are adopted. There are two fundamental modes; one is intra-mode applying two-dimensional DCT to the intrafield blocks, and the other is inter-mode applying horizontal one-dimensional DCT to the interfield or interframe blocks in consideration of statistical characteristics of each signal. B-Code is adopted for variable length coding to obtain better word synchronism recovery properties.

2. GENERAL CODEC OUTLINE

Block diagrams of the encoder and the decoder are shown in Figures 2.1 and 2.2. The coding is carried out on a field basis with interlaced scanning.

The input and output signal format meets CCIR Rec. 601. Preprocessing is done using a two-dimensional low-pass filter which eliminates the spatial diagonal higher frequency region.

Forward motion estimated prediction is performed for both interfield and interframe. Neither backward prediction nor temporal interpolation technique is applied.

Depending on the prediction mode, signals to be coded have distinctive characteristics. Different transform coding, quantization, and variable length coding suitable for each prediction mode should be employed to achieve both higher coding efficiency and higher picture quality, accordingly.

Intra-pictures and inter-pictures are transformed by two-dimensional DCT and horizontal one-dimensional DCT respectively.

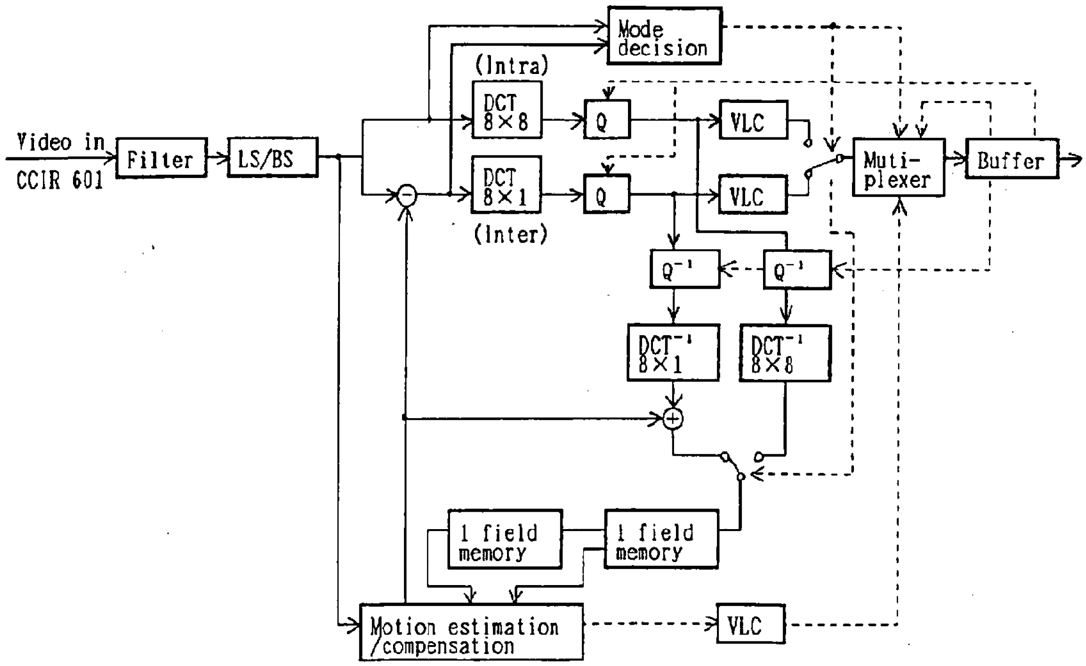

Figure 2.1 Block diagram of the encoder

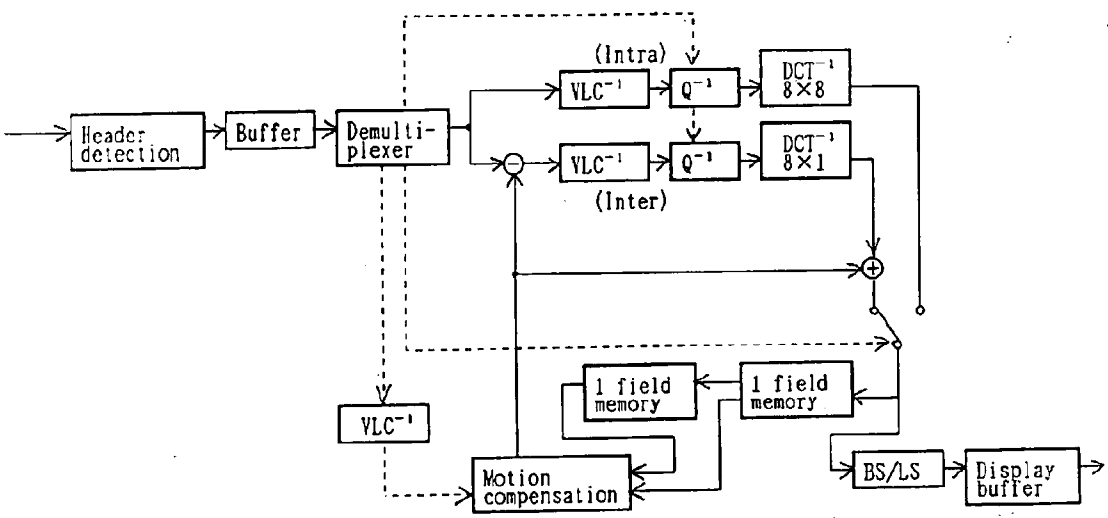

Figure 2.2 Block diagram of the decoder

The quantization characteristics to be used are coarser for higher frequency coefficients of intra-picture, and coarser for luminance than for chrominance. On the other hand, flat characteristics are used for inter-picture. The quantization parameter controls bit rate.

B-Code is employed for the variable length coding.
As for the DCT coefficients, combinations of zero-run length and the following nonzero value are encoded with different code assignments depending on the prediction mode, luminance or chrominance, and the target bit rate.

As for motion vectors, the differential vectors between the global motion vector of a field and the local motion vector of each macroblock are encoded.

A periodic structure of inserted intra-pictures ensures random access and fast search functions, etc.

3. SOURCE FORMAT

3.1 Input and Output Signals

The input and output picture format is the 525-line version of the 4:2:2 level of CCIR Rec. 601.
The coded region is 704 pixels x 240 lines for the luminance signal and 352 pixels x 240 lines for the chrominance signal, respectively, by cropping the left and right edges of input signals. The field rate is 59.94 Hz.
For processing purposes an offset of -128 is added to each video signal. Thus, the range of the video signal level is -128 to 127.

3.2 Pre- and Postprocessing

Two-dimensional low-pass filter eliminates the spatial diagonal higher frequency region of the input signal for both luminance and chrominance. This is based on the human visual property which has lower resolution in diagonal directions. Using this preprocessing, higher coding efficiency can be obtained while degradation of picture quality remains minimal.
Filtering is performed on a field signal. The filter coefficients are shown in Table 3.1.
Although postprocessing is also possible in the same manner, it is not done in this simulation.

Table 3.1 Filter coefficients of the two-dimensional low-pass filter

0	2	0	2	0	2	0	
3	0	-8	0	-8	0	3	
0	-11	-2	40	-2	-11	0	
3	0	47	136	47	0	3	
0	-11	-2	40	-2	-11	0	
3	0	-8	0	-8	0	3	
0	2	0	2	0	2	0	//256

```
+----->Horizontal
|
|
v
 Vertical
```

4. LAYERED STRUCTURE OF VIDEO DATA

4.1 BLOCK

A block consists of an array of 8 pixels x 8 lines of either luminance or one

of the color difference signals. Each block is field-based. Transformation and quantization are performed at the block level.

4.2 MACROBLOCK (MB)

A macroblock consists of 2 horizontally adjacent luminance blocks (16 pixels x 8 lines) and the co-sited single 8 x 8 Cb block and single 8 x 8 Cr block. The MB type (intra or inter) is determined on the MB level. Motion compensation is also performed at the MB level.

4.3 SLICE

A slice consists of a row of 44 MBs across the complete width of the picture field (704 pixels x 8 lines for luminance and 352 x 8 for chrominance). Adjustment of quantization is also done on the slice level to control bit rate.

4.4 PICTURE

A picture consists of 30 slices (704 pixels x 240 lines for luminance and 352 x 240 for chrominance).
The picture type (intra or predicted) is determined on the picture level.

4.5 GROUP OF PICTURES (GOP)

A GOP consists of 24 fields. The first field is intra-coded, the second predicted from the previous field, and the following 22 predicted from the previous field and frame within a GOP. This facilitates random access and fast forward/reverse. Also, it assures a total renewal of data every GOP to prevent errors from spreading.

5. MOTION ESTIMATION AND COMPENSATION

Forward motion compensated prediction technique is employed on both interfield and interframe to exploit temporal redundancy. Neither backward prediction nor temporal interpolation is used. This helps reduce processing delay, hardware complexity and memory cost.

Motion estimation is performed on a 16-pixel x 8-line area of luminance signals of each macroblock by means of block matching method. Motion vectors are calculated on comparison between the decoded picture and the original picture. The range of motion vectors are +/- 15.5 pixels and +/- 6.5 lines (field lines) in half pel and line accuracy.

Motion estimation is carried out in two steps. At the first stage, one candidate motion vector is obtained by an integer pel and line search in the range of +/- 15 pixels and +/- 6 lines. At the second stage, a final motion vector is obtained by searching half pel and line displaced positions around the candidate vector.
The picture values at picture edges are interpolated outward when searching motion vectors.

The interpolation filter to provide half pel accuracy is a bilinear filter in both directions.
The matching criteria are based on the sum of the 16 x 8 absolute differences of luminance samples in a macroblock. The motion vector which gives the mini-

mum value is chosen. If two or more positions have the same total value, the shortest vector is chosen.

Motion compensation is performed on both the luminance and chrominance signals within each macroblock. The horizontal component of the motion vector for the chrominance signal is derived by halving that of the luminance signal in the same macroblock. The vertical component is identical to that of the luminance.

6. MODES AND MODE SELECTION

6.1 Picture Types

There are three types of picture field:

(1) Intra: All the macroblocks are coded intrafield.

(2) Predicted-1: Macroblocks may be coded intrafield or motion compensated interfield.

(3) Predicted-2: Macroblocks may be coded intrafield or motion compensated interfield or motion compensated interframe.

Three types of picture are used periodically. The first field of a GOP is coded as "Intra", the second one is coded as "Predicted-1", and the remaining 22 in a GOP are coded as "Predicted-2".

6.2 Macroblock Types in Predicted-picture

Macroblock selection in a predicted-picture is done in the following order:
(1) MC/No MC: The decision whether to make use of the motion compensation is based on the comparison between the sum of absolute field (frame) differences and that of displaced field (frame) differences of all the luminance pels in a macroblock. The selection is to minimize the value. If the both have the equal value, the motion compensation is not used.

(2) Interfield/Interframe: Selection is based on the smallest sum of absolute prediction errors in a macroblock. If both values are equal, the interfield-mode has priority.

(3) Intra/Inter: Decision is based on the comparison between the sum of absolute values subtracted by the mean value of a macroblock of the intra-signal and that of absolute prediction errors multiplied by 134/128 of the inter-signal in a macroblock. If both values are equal, intra-mode is selected.

7. TRANSFORMATION

For each component (Y, Cb, or Cr), discrete cosine transform (DCT) is applied to each block.
Two-dimensional (8 pixels x 8 lines) DCT is applied for intra-mode blocks, and horizontal one-dimensional (8 pixels x 1 line) DCT is applied for those of inter-mode depending on macroblock types.

Because of the well-known fact that interlaced images produce aliasing components in the vertical higher frequency region, motion compensated prediction errors to be coded have little correlation in the vertical direction. Thus,

applying DCT in the vertical direction is not efficient for inter-mode signals in interlaced images. Moreover, the mosquitoes caused by edges in a DCT block do not spread vertically in the case of horizontal one-dimensional DCT, where picture quality will be improved.

8. QUANTIZATION

The DCT coefficients are quantized based on blocks of 8 pixels x 8 lines. Transform coefficients are first weighted with individual weighting factors which is function of the coefficient order, and then divided linearly by the quantization parameter which is the quantizer's rate control parameter, and last quantized by the nearly linear characteristic. These processes are described by the formula;

$$i[u,v] = f(\, c[u,v] \times 8 / w[u,v] / QP \,) \qquad (8.1)$$

where c[u,v] is the DCT coefficient, w[u,v] is the corresponding element of the weighting matrix, QP is the quantization parameter, f(.) is the nearly linear function, and i[u,v] is the resultant index.

The weighting factors are different according to the macroblock type. As for intra-blocks, the factors vary two-dimensionally so as to provide coarser quantization for spatial diagonal higher frequency coefficients and differ from each other for luminance and chrominance signals. These characteristics are based on CCIR Rec. 723. On the other hand, for inter-blocks, 8 horizontal DCT blocks are combined vertically to make 8 x 8 blocks. The weighting factors have a flat characteristic for both luminance and chrominance signals. The weighting factors are shown in Figures 8.1 and 8.2.

8	8	10	16	22	38	54	64
8	13	13	19	32	38	54	64
8	13	19	27	38	45	64	64
10	13	22	32	38	45	64	64
13	22	27	32	45	54	64	64
19	27	27	38	54	64	64	64
27	32	32	38	54	64	64	64
27	38	38	45	64	64	64	64

Luminance

8	8	10	10	13	16	16	17
8	9	10	11	13	16	17	17
10	10	10	11	15	17	17	17
10	11	12	12	16	17	17	17
12	13	13	15	17	17	17	17
15	16	17	17	17	17	17	17
17	17	17	17	17	17	17	17
17	17	17	17	17	17	17	17

Chrominance

Figure 8.1 Weighting matrices for intra-block

16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16

Figure 8.2 Weighting matrix for inter-block

The quantization parameter varies from 1 to 255 according to rate control.

The nearly linear quantizer has characteristics which are linear within the

range of +/-255 with step 1, from +/-256 to +/-511 with step 2, from +/-512 to +/-1024 with step 4, and from +/-1025 to +/-2047 with step 8.

The arithmetic operation of integer division for intra-block DC coefficients rounds up or down to the nearest integer, and that for other coefficients truncates towards zero.

For inter-blocks, the same variable thresholding as SM3 is performed before quantization, and isolated value removal, which replaces +/-1 between zero-runs along the scanning order with 0, is performed after quantization. These operations occur only at the encoder. The scanning orders are described in 9.5 (Figures 9.1 and 9.2).

9. CODING

9.1 B-Code

For variable length coding (VLC), we adopted B-Code which is one of the candidates in CCIR Rec. 723. In B-Code, a word consists of an even number of bits, organized as follows: bits holding odd positions called "continuation bits" are all set to 1 with the exception of the last one in each word, while even ones called "information bits" are freely encoded by information. The words expressed in B-Code have the following structure where X denotes the information bit;

Table 9.1 B-Code structure

word length (bits)	number of words	word structure
2	2	0X
4	4	1X0X
6	8	1X1X0X
8	16	1X1X1X0X
:	:	:
:	:	:

Word synchronism information can be easily obtained from the odd bits, thus B-Code has the desirable features of better word synchronism recovery properties.

9.2 Picture Type

Three kinds of picture types are coded with a 2-bit word.

Table 9.2 Code for picture types

Picture Types	Code
Intra	00
Predicted-1	01
Predicted-2	10

9.3 Macroblock Type

Each picture field has one of the three modes, intra, predicted-1, or predict-

ed-2. According to these three modes, different VLC tables are used for each macroblock type.

Since intra-fields have only the intra-MB type, no code for MB type is assigned for them.

Predicted-1-fields have the following MB types, with their respective codes.

Table 9.3 Code for macroblock types for predicted-1-fields

Macroblock Types	Code
Intra	00
MC Interfield	01
No MC Interfield	1000

Predicted-2-fields have the following MB types, with their respective codes.

Table 9.4 Code for macroblock types for predicted-2-fields

Macroblock Types	Code
Intra	1000
MC Interfield	01
No MC Interfield	1001
MC Interframe	00
No MC Interframe	1100

9.4 Motion Vector

Motion vectors are coded by means of both global motion vector and local motion vector.
The global motion vector represents the motion as a full picture, while the local motion vector does that of each macroblock. In this simulation, the global motion vector is obtained by the motion vectors of macroblocks having the same macroblock types (MC interfield or MC interframe) averaged over a picture.
It is preferable that the global motion vector be derived by a global motion estimation.

The global motion vectors are coded with a 6-bit word per picture for each horizontal and vertical component.

The local motion vectors are represented as differential motion vectors between the global motion vector and the local motion vector in each macroblock, and then coded according to the B-Code principle.
A 1-bit flag for each horizontal and vertical component is assigned to inform whether the vector is zero or not, and only if it is not zero, the vector is coded using the following VLC table. Even though this table shows only the word length, code words are easily obtained according to the B-Code principle. Both horizontal and vertical components are coded with the same VLC table.

Table 9.5 Number of bits used for the VLC for motion vectors

Motion Vector	word length(bits)
+/- 0.5	2
+/- 1.0 .. 1.5	4
+/- 2.0 .. 3.5	6
+/- 4.0 .. 7.5	8
+/- 8.0 .. 15.5	10
+/-16.0 .. 31.0	12

9.5 Transform Coefficient

After the DCT coefficients have been quantized, they are coded in different manners for intra-picture and predicted-picture.

The suitable VLC tables depend on the target bit rate. In this simulation, two kinds of tables are available for each target bit rate (4M and 9M) at the encoder and the decoder, and the table to be used is identified by the sequence header.

9.5.1 Intra-picture

The DC coefficients are coded without loss by DPCM technique from left to right in a slice. At the left edge of the slice, the value itself is coded. The VLC table for these DC coefficients are shown in Table 9.6.

Table 9.6 Number of bits used for the VLC for DC coefficients of intra-picture.

LEVEL	word length(bits)
0, -1	2
+1 .. +2, -2 .. -3	4
+3 .. +6, -4 .. -7	6
+7 .. +14, -8 .. -15	8
+15 .. +30, -16 .. -31	10
+31 .. +62, -32 .. -63	12
+63 .. +126, -64 .. -127	14
+127 .. +254, -128 .. -255	16
+255 .. +510, -256 .. -511	18
+511 .. +1022, -512 .. -1023	20
+1023 .. +1278, -1024 .. -1278	22

The AC coefficients are sequentially transmitted according to the zigzag scanned orders shown in Figure 9.1 in a 8 x 8 block. These scanned orders differ between luminance and chrominance signals. The combinations of zero-run length (RUN) and the following nonzero value (LEVEL) are coded. EOB (End of block) is appended to the last coded data in a block. When the last data in a block is zero-run, the zero-run is replaced by EOB.

0	2	6	12	20	28	36	44
1	5	11	19	27	35	43	51
3	7	13	21	29	37	45	52
4	10	18	26	34	42	50	57
8	14	22	30	38	46	53	58
9	17	25	33	41	49	56	61
15	23	31	39	47	54	59	62
16	24	32	40	48	55	60	63

Luminance

0	2	3	9	10	20	21	35
1	4	8	11	19	22	34	36
5	7	12	18	23	33	37	48
6	13	17	24	32	38	47	49
14	16	25	31	39	46	50	57
15	26	30	40	45	51	56	58
27	29	41	44	52	55	59	62
28	42	43	53	54	60	61	63

Chrominance

Figure 9.1 Zigzag scanned orders for intra-block

The most commonly occurring combinations of successive zeros and following value are encoded with two-dimensional (RUN,LEVEL) VLC tables as listed in Tables 9.7 to 9.10.

Other combinations are encoded by the ESC-sequence with a word consisting of 12-bit ESCAPE, RUN and LEVEL as listed in Tables 9.11 and 9.12. The excuse is that these tables contain only word lengths. Although duplicate code words are assigned to both RUN and LEVEL, it is able to distinguish between RUN and LEVEL according to its order in sequences.
Different VLC tables are used for luminance and chrominance.
The EOB word length for intra-pictures is 4 bits.

Table 9.11 Number of bits used for one-dimensional VLC for RUN of intra-picture

RUN	VLC Length(bits)
0 .. 1	2
2 .. 4, EOB	4
5 .. 12	6
13 .. 28	8
29 .. 60	10
61 .. 63, ESC	12

Table 9.12 Number of bits used for one-dimensional VLC for LEVEL of intra-picture

LEVEL	VLC Length(bits)
+9, -9	2
+10 .. +11, -10, EOB	4
+12 .. +15, -11 .. -14	6
+16 .. +23, -15 .. -22	8
+24 .. +39, -23 .. -38	10
+40 .. +70, -39 .. -70, ESC	12
+71 .. +134, -71 .. -134	14
+135 .. +262, -135 .. -262	16
+263 .. +518, -263 .. -518	18
+519 .. +639, -519 .. -639	20

Table 9.7 Number of bits used for two-dimensional VLC for luminance of intra-picture at 4Mbps

LEVEL \ RUN	0	1	2	3	4	5	6	7	8	9	10··15	16	17··21	22··31	32··61	62··63
1	2	6	6+	8	8+	10	10	10	12	12	14	14	16	16	16	18
2	4	8	10	10	12	12	12	14	14	16	16	16	16	16	18	18
3	4+	8	10	12	12	14	14	14	16	16	16	18	18	18	18	18
4	6	10	12	12	14	14	14	16	16	16	16	18	18	18	18	18
5	6	10	12	14	14	16	16	16	18	18	18	18	18	18	18	18
6	8	12	14	14	14	16	16	16	18	18	18	18	18	18	18	18
7	8	12	14	14	16	16	16	16	18	18	18	18	18	20	20	20
8	8	12	14	14	16	16	16	16	20	20	20	20	20	20	20	20
9	8	12	14	14												
10 : 11	10	12	14	16												
12	10	14	14	16												
13 : 16	10	14	16	16												
17	10+	14														
18 : 24	12	14														
25 : 32	12	16										EACAPE + RUN + LEVEL				
33 : 54	14	20														
55 : 64	16	20														
65 : 128	20	20														
129 : 639																

Note : "+" means that additional 2 bits are required for negative LEVEL.

Table 9.8 Number of bits used for two-dimensional VLC
for chrominance of intra-picture at 4Mbps

LEVEL \ RUN	0	1	2	3	4	5	6	7	8··9	10	11··15	16··17	18··21	22··25	26··31	32··63
1	2	4+	6	8	8	8	8	10	10	10	12	12	14	14	16	16
2	4	8	10	10	10	12	12	12	12	14	14	16	16	16	16	18
3	6	8+	10+	12	12	14	14	14	16	16	16	18	18	18	18	18
4	6	10	12	12	14	14	14	14	16	16	16	18	18	18	18	18
5	6+	10	12	14	14	14	16	16	18	18	18	18	18	18	18	18
6	8	12	12	14	14	16	16	16	18	18	18	18	18	18	18	18
7	8	12	14	14	14	16	16	16	18	18	18	18	18	20	20	20
8	10	12	14	14	16	16	16	16	20	20	20	20	20	20	20	20
9	10	14	14	14												
10 : 13	10	14	14	16												
14	12	14	14	16												
15 : 16	12	14	16	16												
17 : 19	12	14														
20 : 23	12	16														
24 : 32	14	16							EACAPE + RUN + LEVEL							
33 : 38	14	20														
39 : 62	16	20														
63 : 64	18	20														
65 : 128	20	20														
129 : 639																

Note : "+" means that additional 2 bits are required for negative LEVEL.

MS-MOTO_752_0001230204

MS-MOTO_1823_00000720724

Table 9.9 Number of bits used for two-dimensional VLC for luminance of intra-picture at 9Mbps

LEVEL \ RUN	0	1	2	3	4	5	6	7	8	9··14	15	16··21	22··29	30··63
1	2	6	8	8	10	10	10	12	12	14	16	16	16	16
2	4	8	10	12	12	12	14	14	16	16	16	16	16	18
3	4+	10	12	12	14	14	14	16	16	16	16	18	18	18
4	6	10	12	14	14	14	16	16	16	16	16	18	18	18
5	6	10	14	14	14	16	16	16	18	18	18	18	18	18
6	6+	12	14	14	16	16	16	16	18	18	18	18	18	18
7	8	12	14	14	16	16	16	16	18	18	18	18	20	20
8	8	12	14	16	16	16	16	16	20	20	20	20	20	20
9 : 10	8	12	14	16										
11	8+	14	16	16										
12 : 16	10	14	16	16										
17 : 19	10	14												
20	10+	14												
21 : 24	12	14												
25 : 32	12	16							EACAPE + RUN + LEVEL					
33 : 38	12	20												
39 : 64	14	20												
65 : 128	20	20												
129 : 639														

Note : "+" means that additional 2 bits are required for negative LEVEL.

Table 9.10 Number of bits used for two-dimensional VLC
for chrominance of intra-picture at 9Mbps

LEVEL \ RUN	0	1	2	3	4	5	6	7	8··10	11··12	13··14	15	16··17	18··21	22··31	32··62	63
1	2	4+	6+	8	8	10	10	10	10	12	12	14	14	16	16	16	18
2	4	8	10	10	12	12	12	12	14	14	16	16	16	16	16	18	18
3	6	8+	12	12	14	14	14	14	16	16	16	16	18	18	18	18	18
4	6	10	12	14	14	14	14	16	16	16	16	18	18	18	18	18	18
5	6	10+	14	14	14	16	16	16	18	18	18	18	18	18	18	18	18
6	8	12	14	14	16	16	16	16	18	18	18	18	18	18	18	18	18
7	8	12	14	16	16	16	16	16	18	18	18	18	18	18	20	20	20
8	8	12	14	16	16	16	16	16	20	20	20	20	20	20	20	20	20
9	8	12	14	16													
10 : 15	10	14	16	16													
16	12	14	16	16													
17 : 18	12	14															
19 : 31	12	16															
32	14	16										EACAPE + RUN + LEVEL					
33 : 62	14	20															
63 : 64	16	20															
65 : 128	20	20															
129 : 639																	

Note : "+" means that additional 2 bits are required for negative LEVEL.

9.5.2 Predicted-picture

The DCT coefficients of intra-blocks in predicted-pictures are scanned accordng to the same zigzag scanned orders as shown in Figure 9.1. On the other hand, the coefficients of inter-blocks are scanned according to the vertical scanned order shown in Figure 9.2, common to both luminance and chrominance signals.

0	15	16	31	32	47	48	63
1	14	17	30	33	46	49	62
2	13	18	29	34	45	50	61
3	12	19	28	35	44	51	60
4	11	20	27	36	43	52	59
5	10	21	26	37	42	53	58
6	9	22	25	38	41	54	57
7	8	23	24	39	40	55	56

Figure 9.2 Vertical scanned order for inter-block

The combinations of zero-run length and the following nonzero value are encoded in the same manner as intra-picture AC coefficients. The two-dimensional VLC tables for predicted-pictures are listed in Tables 9.13 to 9.16. The remaining combinations are coded by the same ESC-sequence as intra-picture with VLC tables listed in Tables 9.17 and 9.18.
The EOB word length for predicted-pictures is 2 bits.

Table 9.17 Number of bits used for one-dimensional VLC for RUN of predicted-picture

RUN	VLC Length(bits)
0, EOB	2
1 .. 4	4
5 .. 12	6
13 .. 28	8
29 .. 60	10
61 .. 63, ESC	12

Table 9.18 Number of bits used for one-dimensional VLC for LEVEL of predicted-picture

LEVEL	VLC Length(bits)
+9, EOB	2
+10 .. +11, -9 .. -10	4
+12 .. +15, -11 .. -14	6
+16 .. +23, -15 .. -22	8
+24 .. +39, -23 .. -38	10
+40 .. +70, -39 .. -70, ESC	12
+71 .. +134, -71 .. -134	14
+135 .. +262, -135 .. -262	16
+263 .. +518, -263 .. -518	18
+519 .. +639, -519 .. -639	20

Table 9.13 Number of bits used for two-dimensional VLC
for luminance of predicted-picture at 4Mbps

LEVEL \ RUN	0	1	2	3	4	5	6	7	8··10	11	12··15	16··17	18··21	22··31	32··52	53··63
1	2+	4+	6	6+	8	8	8	8	10	10	10	12	12	12	14	16
2	4	6	8	8	8	10	10	10	10	10+	12	12	14	14	18	18
3	6	10	12	12	12	12	12	12	14	14	14	18	18	18	18	18
4	8+	12	14	14	14	14	14	14	14	14	16	18	18	18	18	18
5	12	14	14	14	14	14	14	16	18	18	18	18	18	18	18	18
6	12	14	16	16	16	16	16	16	18	18	18	18	18	18	18	18
7	14	16	16	16	16	16	16	16	18	18	18	18	18	20	20	20
8	14	16	16	16	16	16	16	16	20	20	20	20	20	20	20	20
9 : 10	14	16	16	16												
11 : 16	16	16	16	16												
17 : 32	16	16														
33 : 62	16	20							EACAPE + RUN + LEVEL							
63 : 64	18	20														
65 : 128	20	20														
129 : 639																

Note : "+" means that additional 2 bits are required for negative LEVEL.

MS-MOTO_752_0001230208

MS-MOTO_1823_00000720728

Table 9.14 Number of bits used for two-dimensional VLC for chrominance of predicted-picture at 4Mbps

LEVEL \ RUN	0	1	2	3	4	5	6	7	8··10	11	12	13	14	16··17	18	19··21	22··31	32··59	60··63
1	2+	4+	6	6	6	6+	8	8	8	8	8+	10	10	10	10+	12	12	14	16
2	4	10	10	10	10	10	10	10	12	12	12	12	12	12	14	14	14	18	18
3	8	12	12	12	12	14	14	14	14	14	14	14	16	18	18	18	18	18	18
4	10	12	14	14	14	14	14	14	14	16	16	16	16	18	18	18	18	18	18
5	10	14	14	14	16	16	16	16	18	18	18	18	18	18	18	18	18	18	18
6	10	16	16	16	16	16	16	16	18	18	18	18	18	18	18	18	18	18	18
7	12	16	16	16	16	16	16	16	18	18	18	18	18	18	18	18	20	20	20
8	12	16	16	16	16	16	16	16	20	20	20	20	20	20	20	20	20	20	20
9	12	16	16	16	EACAPE + RUN + LEVEL														
10	14	16	16	16															
11 : 16	16	16	16	16															
17 : 32	16	16																	
33 : 62	16	20																	
63 : 64	18	20																	
65 : 128	20	20																	
129 : 639																			

Note : "+" means that additional 2 bits are required for negative LEVEL.

Table 9.15 Number of bits used for two-dimensional VLC
for luminance of predicted-picture at 9Mbps

LEVEL \ RUN	0	1	2	3	4	5	6	7	8	9··13	14	15	16	17··21	22··23	24··31	32··41	42··63
1	2+	6	6+	8	8	8	8+	10	10	10	10+	12	12	12	12	14	14	16
2	4	6	8	8	10	10	10	10	10	12	12	12	12	14	14	14	18	18
3	4+	8	10	12	12	12	12	12	12	14	14	14	18	18	18	18	18	18
4	6	10	12	12	12	14	14	14	14	14	16	16	18	18	18	18	18	18
5	8	12	14	14	14	14	14	16	18	18	18	18	18	18	18	18	18	18
6	10	12	14	14	14	16	16	16	18	18	18	18	18	18	18	18	18	18
7	12	14	14	16	16	16	16	16	18	18	18	18	18	18	20	20	20	20
8	12	14	16	16	16	16	16	16	20	20	20	20	20	20	20	20	20	20
9	12	16	16	16														
10 : 13	14	16	16	16														
14 : 16	16	16	16	16														
17 : 32	16	16																
33 : 62	16	20									EACAPE + RUN + LEVEL							
63 : 64	18	20																
65 : 128	20	20																
129 : 639																		

Note : "+" means that additional 2 bits are required for negative LEVEL.

MS-MOTO_752_0001230210

MS-MOTO_1823_00000720730

Table 9.16 Number of bits used for two-dimensional VLC
for chrominance of predicted-picture at 9Mbps

LEVEL \ RUN	0	1	2	3	4	5	6‥7	8	9	10	11‥15	16	17	18	19‥21	22‥30	31	32‥50	51‥63
1	2+	4+	6	6	6	6+	8	8	8	8	10	10	10+	12	12	12	14	14	16
2	4	8	8+	10	10	10	10	10	10	12	12	12	12	12	14	14	14	18	18
3	8	12	12	12	12	14	14	14	14	14	14	18	18	18	18	18	18	18	18
4	10	14	14	14	14	14	14	14	16	16	16	18	18	18	18	18	18	18	18
5	10	14	14	14	14	16	16	18	18	18	18	18	18	18	18	18	18	18	18
6	12	14	16	16	16	16	16	18	18	18	18	18	18	18	18	18	18	18	18
7	12	16	16	16	16	16	16	18	18	18	18	18	18	18	18	20	20	20	20
8 : 10	12	16	16	16	16	16	16	20	20	20	20	20	20	20	20	20	20	20	20
11 : 16	14	16	16	16	EACAPE + RUN + LEVEL														
17	14	16																	
18 : 32	16	16																	
33 : 62	16	20																	
63 : 64	18	20																	
65 : 128	20	20																	
129 : 639																			

Note : "+" means that additional 2 bits are required for negative LEVEL.

10. VIDEO MULTIPLEX CODER

The video multiplex is arranged in a hierarchical structure with six layers. A syntax diagram of the video multiplex coder is shown in Figure 10.1.

Sequence Layer

```
--SEQSC--HSIZE--VSIZE--ASRAT--FRATE--VLC--UD-+-GOP Data-+-SEQEC
                                             +----<-----+
```

Group of Picture Layer

```
-+-GOPSC -+-Picture Data-++
 |        +------<-------+|
 +-----------<------------+
```

Picture Layer

```
                      +--- TIMECODE ---+
-+-PSC--TR--PTYPE-+-GLMVD1--GLMVD2-++-Slice Data-++
 |                                  +------<-----+|
 +-----------------------------<-----------------+
```

Slice Layer

```
-+-SSC--SVP--SQUANT-+-MB data-+-STUFF-+
 |                  +----<----+       |
 +----------------<-------------------+
```

Macroblock Layer

```
   +-----------»-------------+
   |        +--->--+ +--->--+ |
-+-+-MTYPE-+-MVD1-+--+-MVD2-+-++-Block Data-++
 |                            +------<-----+|
 +--------------------<--------------------+
```

Block Layer

```
    +---->----+
-+-++-TCOEFF-++-EOB-+
 | +----<----+      |
 +--------<---------+
```

Figure 10.1 Syntax diagram of the video multiplex coder

Each layer consists of the following data.

10.1 Sequence Layer

Data for the Sequence Layer consists of:
- Sequence start code (SEQSC) [32 bits]
  0000 0000 0000 0000 0000 0001 1011 0011
- Horizontal picture size (HSIZE) [12 bits]
  0010 1100 0000
- Vertical picture size (VSIZE) [12 bits]
  0000 1111 0000

- Pixel aspect ratio (ASRAT) [4 bits]
  1100
- Picture rate (FRATE) [4 bits]
  0100
- VLC indicator (VLC) [2 bits]
  01 for 4M, 10 for 9M
- User data (UD) [30 bits]
- Data for Group of Pictures
- Sequence end code (SEQEC) [32 bits]
  0000 0000 0000 0000 0000 0001 1011 0111

10.2 Group of Picture Layer

Data for the Group of Pictures Layer consists of:
- Group of Pictures start code (GOPSC) [32 bits]
  0000 0000 0000 0000 0000 0001 1011 1000
- Data for Pictures

10.3 Picture Layer

Data for the Picture Layer consists of:
- Picture start code (PSC) [32 bits]
  0000 0000 0000 0000 0000 0001 0000 0000
- Temporal reference (TR) [6 bits]
- Picture type information (PTYPE) [2 bits]
- Global motion vector data for MC Interfield(GLMVD1) [6+6 bits]
- Global motion vector data for MC Interframe(GLMVD2) [6+6 bits]
- Timecode for Intra picture (TIMECODE) [24 bits]
- Data for Slices

10.4 Slice Layer

Data for the Slice Layer consists of:
- Slice start code (SSC) [16 bits]
  0000 0001 0000 0001
- Slice vertical position (SVP) [8 bits]
- Quantization parameter(SQUANT) [8 bits]
- Data for Macroblocks
- Stuffing bits (STUFF) [0-15 bits]

10.5 Macroblock Layer

Data for the Macroblock Layer consists of:
- Macroblock type (MTYPE) [VLC]
- Differential motion vector data for MC Inter field (MVD1) [VLC]
- Differential motion vector data for MC Inter frame (MVD2) [VLC]
- Data for Blocks

10.6 Block Layer

Data for the Block Layer consists of:
- Transform coefficients (TCOEFF) [VLC]
- End of block (EOB) [VLC]

11. RATE CONTROL

Rate control is achieved by variation of quantization.
The target number of bits and initial value of the corresponding quantization parameter for each picture type are determined in advance.

The reference buffer occupancy (REFB) is calculated at each slice from the target number of bits, the initial buffer occupancy, and the target bit rate. Meanwhile, the current buffer occupancy (CURB) is observed at each slice. The difference value (DIF) between the reference value and the current value is used to control the quantization parameter (QP). If the current value is smaller than the reference value, the quantization parameter should be made smaller than the initial quantization parameter (QP0). These operations are described as follows;

$$DIF[kbits] = CURB[kbits] - REFB[kbits] \quad (11.1)$$

$$QP = DIF / 10 + QP0 \quad (11.2)$$

The averaged value of the quantization parameters in the current field is used to update the initial quantization parameter for the next same picture type.

12. IMPLEMENTATION ANALYSIS

12.1 Encoder

12.1.1 Buffer

There are two kinds of buffer, one is a picture buffer for motion estimation and motion compensation, the other is a coded data buffer.

- Picture buffer: 2 Fields x 8 bits
  = 338k x 8 bits, 13.5MHz,
  for motion estimation.

  1 Frame x 8 bits
  = 338k x 8 bits, 13.5MHz,
  for motion compensation of chrominance.

- Coded data buffer: 2048k bits

12.1.2 Prefilter

- 7 x 7 two-dimensional low-pass filter (symmetrical filter)

  Memory: 2(Y/C) x 6 H x 8 bits
  = 8k x 8 bits, 13.5MHz
  H: Horizontal scanning line

  Adder: 2(Y/C) x 48, 16bits, 13.5MHz

  Multiplier: 2(Y/C) x 16, 9bits, 13.5MHz

  Delay time: 3 H/13.5MHz

12.1.3 LS/BS

A scan conversion from line scanning (LS) to block scanning (BS) is performed after the preprocessing. This process is illustrated in Figure 12.1.

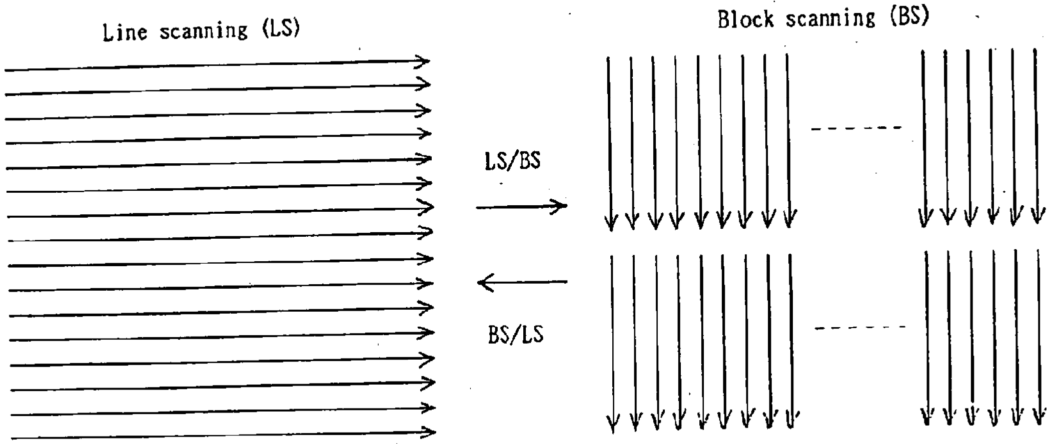

Figure 12.1 Scan conversion

- Line/Block scan conversion

Memory: 2(Y/C) x 16 H x 8 bits
= 22.5k x 8 bits, 13.5MHz

Delay time: 8 H/13.5MHz

12.1.4 Mode Decision

- Intra/Inter mode decision

Multiplication factor 134/128 equals 1 + 1/32 + 1/64.

Memory: 2 MB x 8 bits = 256 x 8 bits, 13.5MHz
MB: Macroblock size = 128 samples

Adder: 3, 15 bits, 13.5MHz, for integration.
2, 8 bits, 13.5MHz, for subtraction and comparison.
2, 15 bits, 13.5MHz, as a multiplier.

Absoluter: 2, 9 bits, 13.5MHz

Delay time: 2 MB/13.5MHz

12.1.5 DCT

- 8 x 1 one-dimensional DCT

Scan conversion
Memory: 2(Y/C) x 1 MB x 8 bits, 13.5MHz

DCT processor (e.g. Fujitsu MB630603)
2(Y/C) x 1, 13.5MHz

(on chip)
Tables: 64 x 14 bits, 13.5MHz, fixed

Adder: 8, 26 bits, 13.5MHz

Multiplier: 8, 14 bits, 13.5MHz

- 8 x 8 two-dimensional DCT

Two-dimensional DCT can be performed by double one-dimensional DCT.

DCT processor (e.g. Inmos IMS A121)
2(Y/C) x 1, 13.5MHz
(on chip)
Tables: 64 x 14 bits, 13.5MHz, fixed

Adder: 8, 26 bits, 13.5MHz, for 1st 1-D DCT.
8, 33 bits, 13.5MHz, for 2nd 1-D DCT.

Multiplier: 8, 14 bits, 13.5MHz, for 1st 1-D DCT.
8, 16 bits, 13.5MHz, for 2nd 1-D DCT.

Memory: 128 x 16 bits, 13.5MHz, for results of 1st DCT.

Delay time: 128/13.5MHz

12.1.6 Quantizer

- Variable thresholding

Table: 2(Y/C) x 64 x 6 bits
= 128 x 6 bits, 13.5MHz, fixed, for scanned orders.

Memory: 2(Y/C) x 128 x 12 bits
= 256 x 12 bits, 13.5MHz

Adder: 2(Y/C), 8 bits, 13.5MHz

- Quantizer

Table: 2(Y/C) x 2(Intra/Inter) x 64 x 7 bits
= 256 x 7 bits, 13.5MHz, fixed, for weighting factors.

2(Y/C) x 2(Intra/Inter) x 2048 x 11 bits
= 8k x 11 bits, 13.5 MHz, fixed, for nearly linear quantizer.

Multiplier: 2(Y/C) x 2(Intra/Inter) x 2, 15 bits, 13.5 MHz

- Isolated value removal

Adder: 2(Y/C) x 2, 11 bits, 13.5 MHz

12.1.7 Inverse Quantizer

Table: 2(Y/C) x 2(Intra/Inter) x 64 x 7 bits
= 256 x 7 bits, 13.5MHz, fixed, for weighting factors.

2(Y/C) x 2(Intra/Inter) x 640 x 12 bits
= 2.6k x 12 bits, 13.5 MHz, fixed, for nearly linear quantizer.

Multiplier: 2(Y/C) x 2(Intra/Inter) x 2, 15 bits, 13.5 MHz

12.1.8 Inverse DCT

- 8 x 1 one-dimensional DCT

Scan conversion
Memory: 2(Y/C) x 1 MB x 8 bits, 13.5MHz

DCT processor x 2(Y/C) (e.g. Fujitsu MB630603)
(on chip)
Tables: 64 x 14 bits, 13.5MHz, fixed

Adder: 8, 29 bits, 13.5MHz

Multiplier: 8, 14 bits, 13.5MHz

- 8 x 8 two-dimensional DCT

Two-dimensional DCT can be performed by double one-dimensional DCT.

DCT processor x 2(Y/C) (e.g. Inmos IMS A121)
(on chip)
Tables: 64 x 14 bits, 13.5MHz, fixed

Adder: 8, 29 bits, 13.5MHz, for 1st 1-D DCT.
8, 33 bits, 13.5MHz, for 2nd 1-D DCT.

Multiplier: 8, 14 bits, 13.5MHz, for 1st 1-D DCT.
8, 16 bits, 13.5MHz, for 2nd 1-D DCT.

Memory: 128 x 16 bits, 13.5MHz, for results of 1st DCT.

Delay time: 128/13.5MHz

12.1.9 Motion Estimation

- The 1st search (integer accuracy)

Motion estimation processor(e.g. Thomson STI3220)
2(Field/Frame) x 2, 13.5 MHz
(on chip)
Adder: 384, 9bits, 13.5MHz

(off chip)
Memory: 2(Field/Frame) x 2 x 16 H x 8 bits
= 45k x 8 bits, 13.5MHz

Adder: 2, 8bits, 13.5MHz

- The 2nd search (half pel accuracy):

Interpolation filter
Memory: 2(Field/Frame) x 1k x 8 bits
= 2k x 8 bits, 54MHz

Adder: 2(Field/Frame) x 1, 8bits, 13.5MHz
2(Field/Frame) x 1, 8bits, 27MHz

Motion estimation processor
2(Field/Frame) x 1, 13.5MHz
(on chip)
Adder: 384, 9bits, 13.5MHz

(off chip)
Memory: 16 H x 8 bits
= 11k x 8 bits, 13.5MHz, for MC by 1st vector.

2(Field/Frame) x 2 x 16H x 8 bits
= 45k x 8 bits, 13.5MHz

Adder: 2, 8bits, 13.5MHz

12.1.10 Motion Compensation (MC) and Prediction

- Interpolation filter for chrominance

Memory: 2(Field/Frame) x 1k x 8 bits
= 2k x 8 bits, 54MHz

Adder: 2(Field/Frame) x 1, 8 bits, 13.5MHz
2(Field/Frame) x 1, 8 bits, 27MHz

- Compensation

Memory: 16 H x 8 bits
= 11k x 8 bits, 13.5MHz, for luminance.

For chrominance, mentioned above (12.1.1).

- Prediction

Adder: 2(Y/C), 8 bits, 13.5MHz

Memory: 2(Y/C) x 14 H x 8 bits
= 20k x 8 bits, 13.5MHz,
for the timing adjustment between input and prediction signal.

Delay time: 14 H/13.5MHz

12.1.11 VLC

- DCT coefficients

  - Scanned order
    Table: 2(Y/C) x 64 x 6 bits
    = 128 x 6 bits, 13.5MHz, fixed, for scanned orders of intra-field.

    64 x 6 bits, 13.5MHz, fixed,
    for scanned orders of predicted-field.

    Memory: 2(Y/C) x 2(Intra/Inter) x 128 x 11bits
    = 512 x 11 bits, 13.5MHz

  - VLC
    Table: 2(Y/C) x 2(Intra/Inter) x 256 x 10 bits
    = 1024 x 10 bits, 13.5MHz, downloaded, for 2-D table-1.

    512 x 10 bits, 13.5MHz, downloaded, for 2-D table-2.

    1024 x 10 bits, 13.5 MHz, downloaded, for 2-D table-3.

- Motion vectors

  Memory: 2(Field/Frame) x 1320 x 5 bits
  = 2.6k x 5 bits, 13.5MHz/128

  Adder: 2(Field/Frame) x 1, 16 bits, 13.5MHz/128
  2(Field/Frame) x 1, 5 bits, 13.5MHz/128

  Multiplier: 2(Field/Frame) x 1, 16 bits, 13.5MHz/128

  Delay time: 1 Field

12.1.12 Rate Control

- Current parameter
  Adder: 1, 8 bits, 1.8kHz, for difference.
  1, 8 bits, 1.8kHz, for reference buffer.
  1, 8 bits, 13.5MHz, for current buffer.
  table: 1 x 8 x 8 bits, -, for initial value.
  1.8kHz = 60Hz x number of slices = 60Hz x 30

- Initial parameter
  Adder: 1, 8 bits, 1.8kHz, for averaging parameters.
  Multiplier: 1 x 13 bits, 1.8kHz

12.2 Decoder

12.2.1 Buffer

- Coded data buffer: 2048k bits

- Picture buffer: 2(Y/C) x 1 Frame x 8 bits
  = 676k x 8 bits, for motion compensation.

  1 Frame x 8 bits
  = 338k x 8 bits, for display buffer.

12.2.2 Inverse VLC

- DCT coefficients

  Inverse VLC
  Table: 2(Y/C) x 2(Intra/Inter) x 1024 x 6 bits
  = 4k x 6 bits, 13.5MHz, downloaded, for RUN.

  2(Y/C) x 2(Intra/Inter) x 1024 x 11 bits
  = 4k x 11 bits, 13.5MHz, downloaded, for LEVEL.

  Scanned order
  Table: 2(Y/C) x 64 x 6 bits
  = 128 x 6 bits, 13.5MHz, fixed, for scanned orders of intra-field.

  64 x 6 bits, 13.5MHz, fixed,
  for scanned orders of predicted-field.

  Memory: 2(Y/C) x 2(Intra/Inter) x 128 x 11bits
  = 512 x 11 bits, 13.5MHz

- Motion vectors

  Adder: 2(Field/Frame) x 1, 6 bits, 13.5MHz/128

12.2.3 Inverse Quantizer

This is the same processing as that of the encoder.

12.2.4 Inverse DCT

This is the same processing as that of the encoder.

12.2.5 Motion Compensation

- Interpolation filter
  Memory: 2(Y/C) x 2(Field/Frame) x 1k x 8 bits
  = 4k x 8 bits, 54MHz

  Adder: 2(Y/C) x 2(Field/Frame) x 1, 8 bits, 13.5MHz
  2(Y/C) x 2(Field/Frame) x 1, 8 bits, 27MHz

- Compensation
  Memory: mentioned above (12.2.1).

- Prediction
  Adder: 2(Y/C), 8 bits, 13.5MHz

12.2.6 BS/LS

A scan conversion from block scanning to line scanning is performed after decoding. This process is illustrated in Figure 12.1.

- Block/Line scan conversion

  Memory: 2(Y/C) x 16 H x 8 bits
  = 22.5k x 8 bits, 13.5MHz

  Delay time: 8 H/13.5MHz

12.3 Global

VLC tables for DCT coefficients are loaded on RAM look-up-tables in both the encoder and the decoder according to coding conditions.

It is preferable that mode decision may be done after VLC coding by comparing the number of bits of both intra-mode and inter-mode. This will improve the hardware complexity and coding efficiency.

There is no non-automatic adjustment of coding parameters.
The target number of bits and initial value of the corresponding quantization parameter for each picture type are determined in advance. They are independent of picture sequences.

13. FUNCTIONALITY

13.1 Compatibility

This coding scheme has "switchable" compatibility. It has neither forward/backward nor upward/downward compatibility by itself. To achieve such compatibility, it needs another standard's encoder and decoder to be embedded.

13.2 Random Access

To achieve random access, a periodic structure of picture types is introduced. In a GOP, every first field is coded intra and the following fields are coded predicted. Every intra-picture has TIMECODE in each picture header. Thus random access to an arbitrary point can be used to search TIMECODE and start intra-picture decoding.

13.3 Coding/Decoding Delay

The coding or decoding delay in each module is listed in Table 13.1 based on the implementation analysis.
According to the simulation results, 1.2M bits at 4Mbps and 1.5M bits at 9Mbps are enough size of the coded data buffer with the initial buffer occupancy of 512k bits. Delay time at the coded data buffer was calculated by these values.

Table 13.1 Coding/Decoding delay

	Module	Delay(msec)	
Encoder	Prefilter	0.2	
	LS/BS	0.4	
	Prediction(MC)	0.7	
	Mode decision	negligible	
	DCT	negligible	
	VLC	17	
---------	Data Buffer	300(4Mbps)	167(9Mbps)
Decoder	MC	0.3	
	Inverse VLC	negligible	
	Inverse DCT	negligible	
	BS/LS	0.4	
Total		319(4Mbps)	186(9Mbps)

14. CODING PARAMETER

The following parameters have been used throughout the simulation. No manual adjustment has been used to adapt each picture sequence. The other parameters have been stated above.

- Buffer size : 2048k bits

- Initial buffer occupancy : 512k bits

- Target number of bits per field:

Table 14.1 Target number of bits per field for each picture type

Picture Type	4M	9M
Intra	490k	900k
Predicted-1	110k	220k
Predicted-2	45k	110k

- Target number of bits per second : 3975k bits for 4M
  8850k bits for 9M

- Initial quantization parameter

Table 14.2 Initial quantization parameter for each picture type

Picture Type	4M	9M
Intra	11	5
Predicted-1	22	10
Predicted-2	27	15

15. STATISTICS

15.1 Number of bits and SNR for each field

(Annex I)

15.2 Cumulative bit count once every 0.4 second

(Annex II)

15.3 Other Statistics

(Annex III)

15.4 Paper listing of coded bit stream file

Table 15.1 Coded bit stream file

```
-rw-rw-r--  1 ynishida  2519446 Oct 16 20:47 flw4.bit
-rw-rw-r--  1 ynishida  5589438 Oct 17 10:24 flw9.bit
-rw-rw-r--  1 ynishida  2516566 Oct 17 10:37 fot4.bit
-rw-rw-r--  1 ynishida  2515734 Oct 16 21:01 mob4.bit
-rw-rw-r--  1 ynishida  5585136 Oct 17 10:32 mob9.bit
-rw-rw-r--  1 ynishida  5588154 Oct 17 10:42 pop9.bit
-rw-rw-r--  1 ynishida  2517404 Oct 16 20:55 tbl4.bit
-rw-rw-r--  1 ynishida  5582850 Oct 17 10:17 tbl9.bit
```

16. CONCLUSION

The main features of this coding scheme are as follows:

(1) Forward motion estimated prediction is performed on a field basis for both interfield and interframe. Neither backward prediction nor temporal interpolation technique is applied. This helps reduce processing delay and hardware complexity.

(2) Horizontal one-dimensional DCT is introduced for inter-blocks as well as two-dimensional DCT for intra-blocks. For the inter-mode signals it prevents mosquitoes from spreading vertically without deterioration in the coding efficiency.

(3) B-Code which has better word synchronism recovery properties is adopted for variable length coding.

17. REFERENCES

(1) MPEG Video Simulation Model Three (SM3).

(2) CCIR Recommendation 723, "Transmission of component-coded digital television signals for contribution-quality applications at the third hierarchical level of CCITT Recommendation G.702".

(3) H.Meyer, et.al., "Optimum Run Length Codes", IEEE Trans. Communications, Vol.COM-22, No.6, June 1974.

Annex I

Number of bits and SNR for each field

Sequence : flower garden
Bit rate : 4Mbps

Institute : NHK
Date : / /91

Field	Bits	SNR(dB) Y	Cb	Cr	Field	Bits	SNR(dB) Y	Cb	Cr
0	502048	32.22	37.89	38.41	50	36272	28.02	34.86	35.66
1	80736	29.49	34.56	35.56	51	34880	27.41	33.37	34.21
2	38560	29.79	35.64	36.41	52	34464	28.38	34.44	35.19
3	42960	28.91	33.74	34.81	53	39088	27.72	33.30	34.13
4	48448	29.53	34.66	35.46	54	39184	28.78	34.26	35.00
5	53152	29.20	33.51	34.57	55	50048	28.15	33.16	34.00
6	50528	29.64	34.44	35.23	56	52592	28.69	33.84	34.73
7	53536	29.52	33.53	34.41	57	63456	28.29	32.89	33.85
8	53456	29.84	34.17	34.94	58	56416	28.50	33.32	34.11
9	53088	29.32	33.19	34.10	59	49344	28.24	32.65	33.54
10	56480	29.05	33.45	34.40	60	48288	28.56	33.09	33.86
11	57328	28.50	32.59	33.69	61	46592	28.66	32.74	33.47
12	53088	28.12	32.68	33.78	62	46656	28.69	32.97	33.75
13	42848	27.69	32.08	33.27	63	46480	28.44	32.56	33.28
14	37856	27.59	32.13	33.28	64	44928	28.37	32.69	33.44
15	37280	27.30	31.69	32.96	65	47152	28.18	32.32	33.07
16	39120	27.10	31.70	33.06	66	51696	27.91	32.26	33.17
17	37552	26.95	31.31	32.73	67	55968	27.54	31.97	33.02
18	35776	26.94	31.46	32.80	68	56304	27.12	31.80	32.92
19	36080	26.77	31.18	32.53	69	46400	26.78	31.50	32.79
20	38896	26.68	31.14	32.46	70	38496	26.68	31.41	32.66
21	47424	26.48	30.92	32.29	71	34624	26.60	31.18	32.46
22	52880	26.54	30.97	32.29	72	501824	31.19	37.18	37.23
23	52176	26.57	30.89	32.28	73	66736	27.77	34.03	34.81
24	522688	31.66	37.56	37.86	74	29920	29.26	35.63	36.33
25	74336	28.72	34.28	35.14	75	33040	27.36	33.44	34.42
26	43504	28.16	34.82	35.74	76	37728	28.22	34.40	35.32
27	38448	27.97	33.61	34.81	77	42384	27.36	32.95	34.04
28	39200	27.80	33.98	34.76	78	44848	28.03	33.76	34.80
29	36224	27.86	33.17	34.26	79	55088	27.83	32.78	34.02
30	37808	27.77	33.53	34.38	80	60864	28.13	33.19	34.49
31	43456	27.83	32.83	34.04	81	62208	28.18	32.61	33.86
32	55920	27.77	32.89	33.93	82	54128	27.96	32.63	33.96
33	53472	27.87	32.50	33.80	83	48256	27.85	32.24	33.52
34	54400	27.70	32.36	33.50	84	45360	27.46	32.17	33.48
35	58368	27.64	32.29	33.63	85	44768	27.25	31.78	33.20
36	58112	27.26	31.99	33.30	86	48944	26.92	31.58	33.15
37	55312	26.97	31.64	33.01	87	53456	26.77	31.48	32.98
38	46592	26.83	31.60	32.95	88	52912	26.53	31.15	32.77
39	41072	26.42	31.19	32.58	89	43648	26.30	30.96	32.62
40	37024	26.38	31.26	32.65	90	41760	26.02	30.74	32.34
41	37136	26.26	30.96	32.34	91	39136	25.87	30.58	32.21
42	35888	26.15	31.05	32.36	92	37952	25.82	30.48	32.06
43	36176	26.04	30.76	32.13	93	35744	25.75	30.37	31.97
44	37232	25.99	30.82	32.13	94	36000	25.75	30.31	31.93
45	40112	26.05	30.62	32.02	95	35728	25.67	30.20	31.85
46	43632	26.19	30.74	32.13	96	542160	30.77	36.65	36.88
47	46192	26.34	30.67	31.96	97	63744	27.24	33.60	34.38
48	541648	31.51	37.45	37.64	98	36736	27.03	34.21	35.19
49	69648	28.13	34.29	34.87	99	35904	26.94	33.29	34.51

Field	Bits	SNR(dB) Y	Cb	Cr	Field	Bits	SNR(dB) Y	Cb	Cr
100	44928	26.32	32.83	33.85	150	59216	27.21	32.99	34.12
101	33888	26.99	32.85	34.04	151	56224	27.18	32.31	33.62
102	36256	26.56	32.60	33.56	152	44208	27.05	32.41	33.53
103	35616	27.16	32.58	33.84	153	37312	27.24	31.99	33.26
104	48416	27.08	32.24	33.46	154	38528	27.37	32.22	33.41
105	60992	27.65	32.39	33.85	155	45984	27.47	31.90	33.21
106	71648	27.40	31.93	33.41	156	57936	27.28	31.82	33.07
107	69632	27.33	31.73	33.16	157	55232	27.08	31.48	32.75
108	54992	27.23	31.67	33.27	158	48096	26.94	31.43	32.65
109	44832	26.74	31.35	32.85	159	42400	26.87	31.25	32.53
110	41920	26.74	31.29	32.80	160	41280	26.91	31.28	32.53
111	38896	26.62	31.09	32.54	161	41616	27.00	31.22	32.41
112	41136	26.50	31.05	32.63	162	38000	27.24	31.35	32.50
113	45360	26.31	30.89	32.51	163	37936	27.05	31.20	32.30
114	48016	25.99	30.78	32.40	164	40768	27.01	31.18	32.35
115	41584	26.02	30.60	32.24	165	47872	26.87	30.98	32.09
116	35264	26.03	30.59	32.11	166	53552	26.85	30.97	32.10
117	35904	26.13	30.48	32.13	167	54384	26.83	30.80	31.90
118	36688	26.03	30.46	32.05	168	528064	30.52	36.35	36.58
119	40912	26.03	30.31	31.99	169	49776	26.21	33.57	34.22
120	556688	31.04	36.73	37.18	170	33408	29.44	35.44	35.72
121	55248	26.91	33.67	34.48	171	55424	27.64	33.26	33.98
122	30368	28.15	35.10	35.76	172	51520	28.51	34.24	34.83
123	37856	26.78	33.10	34.32	173	55744	27.86	32.82	33.62
124	48304	26.57	33.04	34.18	174	51536	27.93	33.33	34.11
125	44160	26.88	32.66	34.12	175	46752	27.74	32.48	33.36
126	43280	26.61	32.45	33.65	176	44640	27.90	32.99	33.80
127	43680	27.00	32.29	33.78	177	43872	27.80	32.27	33.20
128	49472	26.87	32.10	33.39	178	47344	27.72	32.51	33.48
129	52048	27.05	32.01	33.46	179	47392	27.48	31.88	32.87
130	56768	27.01	31.76	33.05	180	44528	27.31	32.01	33.05
131	53200	26.96	31.54	32.95	181	45728	27.14	31.53	32.63
132	47456	26.99	31.50	32.70	182	48352	26.82	31.44	32.71
133	44608	26.98	31.38	32.63	183	48656	26.59	31.10	32.44
134	42528	27.04	31.45	32.53	184	43936	26.32	31.00	32.27
135	40560	27.08	31.35	32.49	185	38928	26.29	30.80	32.10
136	38688	27.16	31.39	32.51	186	40960	26.18	30.73	32.06
137	41888	27.10	31.27	32.46	187	40080	26.14	30.60	32.00
138	49920	27.08	31.21	32.36	188	42544	26.12	30.58	32.01
139	54832	27.02	31.04	32.28	189	40272	26.12	30.50	31.97
140	56384	26.93	30.97	32.15	190	38528	26.31	30.63	31.94
141	52240	26.71	30.75	31.95	191	39456	26.31	30.51	31.85
142	46800	26.52	30.67	31.87	192	551920	30.65	36.38	36.67
143	40672	26.34	30.47	31.69	193	48048	25.99	33.37	34.29
144	524416	30.13	36.06	36.27	194	41600	27.95	34.53	35.32
145	52224	26.24	33.31	33.97	195	50464	27.14	33.20	34.43
146	27968	28.85	35.21	35.71	196	60608	26.79	32.79	33.78
147	41120	26.84	33.05	33.90	197	49376	27.08	32.63	33.94
148	37376	27.86	34.25	35.04	198	47280	26.40	32.15	33.13
149	50928	27.04	32.56	33.78	199	46816	26.45	31.89	33.31

Field	Bits	SNR(dB) Y	Cb	Cr	Field	Bits	SNR(dB) Y	Cb	Cr
200	51024	26.13	31.60	32.92	250	42160	26.75	31.58	32.65
201	49232	25.98	31.28	32.76	251	37248	26.86	31.50	32.74
202	45184	25.96	31.28	32.77	252	40464	26.74	31.43	32.50
203	43360	25.55	30.97	32.45	253	46096	26.61	31.20	32.46
204	44848	25.51	30.86	32.47	254	60016	26.46	30.94	32.10
205	43712	25.11	30.52	32.12	255	64768	26.41	30.88	32.20
206	42400	24.97	30.30	31.93	256	60912	26.05	30.68	31.95
207	38144	24.81	30.11	31.72	257	48096	25.86	30.47	31.89
208	39168	24.68	29.99	31.51	258	38016	25.65	30.35	31.69
209	41952	24.71	29.93	31.54	259	36544	25.43	30.15	31.58
210	43280	24.54	29.91	31.45	260	34464	25.39	30.10	31.48
211	44048	24.52	29.73	31.37	261	34928	25.11	29.88	31.36
212	42704	24.63	29.76	31.33	262	36592	24.92	29.75	31.31
213	42512	24.50	29.57	31.15	263	40304	24.79	29.61	31.14
214	42160	24.57	29.53	31.14	264	552912	29.56	35.51	35.72
215	42864	24.60	29.46	31.04	265	41840	24.73	32.71	33.36
216	563888	30.09	35.96	36.16	266	26304	28.49	34.63	35.02
217	44480	25.37	33.10	33.73	267	40960	25.61	32.41	33.10
218	30448	27.20	34.39	34.91	268	34864	27.17	33.38	34.16
219	36912	25.87	32.79	33.63	269	49696	25.99	31.90	32.94
220	45520	25.81	32.71	33.53	270	47008	26.77	32.51	33.50
221	41184	26.28	32.59	33.65	271	50240	26.47	31.60	32.70
222	45936	25.66	31.97	32.96	272	46112	27.01	32.27	33.25
223	41408	26.34	32.14	33.34	273	49872	27.00	31.70	32.66
224	54912	26.00	31.51	32.59	274	47936	27.46	32.24	33.29
225	58752	26.31	31.66	32.86	275	54224	27.17	31.60	32.45
226	63872	26.23	31.45	32.64	276	54272	27.63	32.02	32.94
227	60752	25.93	31.11	32.28	277	56752	27.46	31.49	32.25
228	41264	26.19	31.23	32.41	278	62384	27.51	31.61	32.48
229	36992	25.78	30.87	32.13	279	58992	27.23	31.16	32.08
230	43696	25.86	30.93	32.24	280	48720	26.95	31.25	32.15
231	49872	25.43	30.47	31.88	281	37296	27.07	31.07	31.91
232	47840	25.31	30.43	31.90	282	35248	27.00	31.17	32.05
233	45248	25.15	30.15	31.75	283	34576	26.89	30.92	31.79
234	42496	25.03	30.10	31.72	284	35104	26.81	31.08	31.98
235	38272	24.96	29.90	31.60	285	36160	26.65	30.78	31.75
236	37520	24.84	29.81	31.43	286	37344	26.39	30.76	31.79
237	38992	24.97	29.76	31.40	287	40128	26.30	30.42	31.39
238	36896	24.94	29.77	31.40	288	564576	29.65	35.51	35.68
239	36720	25.11	29.74	31.37	289	38256	24.47	32.52	33.32
240	560320	30.11	36.03	36.17	290	30592	28.12	34.29	34.70
241	42960	25.28	33.06	33.83	291	64864	26.44	32.19	32.96
242	27232	28.40	34.90	35.40	292	55616	27.13	32.84	33.69
243	39968	26.07	32.67	33.67	293	57808	26.59	31.74	32.71
244	46528	26.81	33.17	34.37	294	60656	26.25	31.63	32.69
245	50656	26.56	32.39	33.64	295	45376	26.19	31.22	32.40
246	55488	26.48	32.17	33.51	296	37936	25.82	31.13	32.29
247	49936	26.72	31.95	33.34	297	42000	25.79	30.75	32.18
248	58432	26.51	31.65	32.90	298	46496	25.30	30.55	31.82
249	51360	26.77	31.60	33.06	299	40640	25.42	30.32	31.90